Accelerating 300mm Conversion using Industry Standards

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Biography

Dev Pillai is Director of the Operational Decision Support Technology group at Intel. He has been involved in 300mm automation and equipment standards program development since 1994. He joined Intel in 1984 and led the design, development and implementation of 200mm Interbay and Intrabay programs. He has a B.S. in Mechanical Engineering, an M.S. in Industrial Engineering and an MBA.

Thomas Abell is the 300mm External Programs Manager at Intel and has been involved with Intel's 300mm program since 1995. He joined Intel in 1991 and has managed multiple programs in the Process Equipment Development group. He received his M.S. and B.S. from Purdue University in Materials Science and Engineering.

Abstract

Wafer size conversions in the semiconductor industry have historically been costly and painful experiences. Each previous wafer size transistion was driven by a single IC manufacturer who bore the brunt of the cost, engineering time and risk.

In 1993 a small group at Intel began to consider the transition from 200mm to the next wafer size. By 1994 industry consensus defined 300mm as the next wafer size and Intel's group began to actively pursue development of a 300mm Factory Vision. It also became evident that the cost and effort associated with executing this transition could not be borne by any one company alone.

Intel and a number of other IC manufacturers realized that the most effective way to drive the 300mm conversion was through planning, consensus and industry guidance. The use of industry standards for process and automation equipment was viewed as critical in focusing the costly development activities, speeding the readiness of equipment and enabling automated 300mm manufacturing.

Intercepting the Process Equipment Development Cycle

A critical aspect of any wafer size conversion is the readiness of an entire factory set of process equipment. Intercepting the development of this equipment with the 300mm requirements was a major objective.

Semiconductor process equipment is among the most complex manufacturing equipment in use today. Development of this equipment from inception to production worthy equipment is a multi-year endeavor that is highly sensitive to the technical demands and maturity of process and mechanical transport capabilities. It is not uncommon for new technologies to require three to five years of development time. It is possible for this development cycle to be shortened to one year but only when the process and mechnical aspects are quite mature. One focus area of Intel's 300mm program was to accelerate the readiness of this new fab toolset by clearly communicating the needed attributes in the early stages of tool

development to make a 300mm conversion attractive.

Process Equipment Development can be separated into two distinct phases. The first phase can be identified as Design Definition. In this phase the equipment supplier is initially focused on identifying customers' requirements for a new generation of equipment. These requirements can affect the fundamental design parameters, define the required technology and resolve differences in how customers will implement the product. These findings may identify market segmentation or reveal multiple options that must be present to satisfy different customers. This market research rapidily becomes complicated if the potential customer base is not unified or is unable to positively indentify their future technical or timing requirements. This is often the case in the highly competitive and fast moving IC manufacturing business.

The Design Definition phase also includes the development of a strategic plan which incorporates the findings from the market research into viable implementation directions. This is a critical juncture in the development of the product as the outcome will define the fundamental design parameters and to a large extent the viability of the product in the marketplace. Beyond this point the cost of changing the fundamental design parameters escalates rapidly. It is, therefore, critical for accurate customer requirements to be defined prior to this point in order to chart the most resource efficient path. Intel targeted delivering accurate and detailed information prior to this point with clear 300mm equipment requirements.

The second phase of Process Equipment Development can be termed Tactical Implementation. This can be characterized by extensive modeling efforts and the construction of prototype process and mechanical transport systems. Engineering decisions involving tradeoffs are made in several stages. These decisions form an iterative development process. Nomenclature varies but this iterative process of tool development can be sequenced as: 1) prototype, 2) alpha tool, 3) beta tool, 4) pre-production tool, and 5) final production tool construction. Decisions at each iteration constrain the final design. Any major changes may require the redesign of many other components resulting in significant additional cost. New customer requirements inserted in the later stages of iteration result in significant expenses in time and resources. It is exactly these expenses that 300mm standards and clear expectations were targeted to reduce.

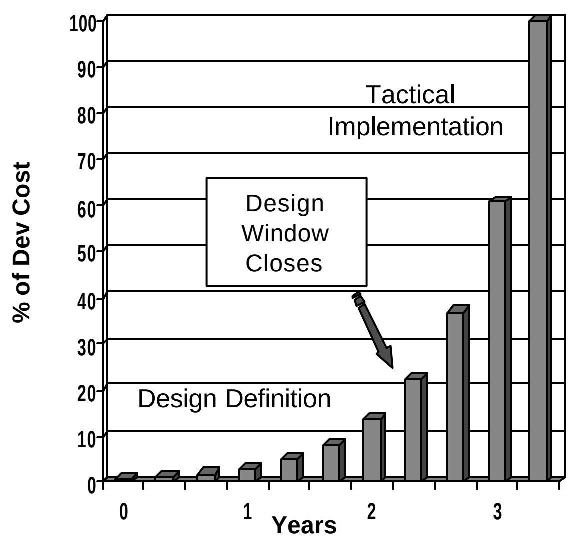

Figure 1: Predicted development cost as a function of time. The transition between development phases is indicated.

Linking to Standards Development Cycle

Linking the development of new standards to the 300mm Process Tool Development Cycle was considered critical. However, the genesis of an industry standard is not an exact science.

The final document that is balloted is the product of considerable discussion, comparison and negotiation. The early stages of standards development are believed to reside in the development of implementation visions by individual customers. Without the development of some type of vision the identification of critical requirements becomes a haphazard endeavor. With the development of these visions (by one or more customers) it is possible that certain aspects of these visions can mature into standards. This happens when there is common agreement among implementation elements of the visions.

Identifying these common elements requires that these visions be shared. This can be especially difficult when the various customers are competitors or perceive the reward of exclusivity to be greater than the gain from consensus. Forums for this type of activity can be created through strategic alliances between customers or on a larger scale through creation of consortia of interested customers. The International 300mm Initiative (I300I) provided this type of forum to share visions between US, European, Taiwanese and Korean IC manufacturers. Japanese manufacturers formed the J300 and SELETE consortia for 300mm. Joint ventures have also served this function with Semiconductor300 (SC300) between Infineon and Motorola being the prime example. The key point, regardless of forum, is the sharing and agreement on common objectives around which standards can be created to define specific mutual requirements.

The transformation of common objectives into detailed specifications is a road heavily travelled by discussion and negotiation. Considerable hours of discussion are required to identify specific areas for specification, in addition to the numerous hours required to arrive at an acceptable document. However, the scrutiny, negotiation and agreement are all critical in developing a set of specifications that are universally recognized. SEMI provides the mechanism in the semiconductor industry for facilitating this process. Many pitfalls exist along the road to creating a standard. Contradictory visions, incompatible objectives, differing motives, meager participation and insufficient scrutiny can all contribute to the demise of promising opportunities. Defacto or informal standards can also have an effect on this process. These defacto standards can be disruptive when they contradict the majority opinion. Or they can be constructive by providing frameworks to build upon. We have seen several cases of defacto standards falling by the wayside in favor of better alternatives (e.g. single wafer lots, large buffering requirements) as well as defacto standards accelerating the process (e.g. I300I equipment metrics).

The prime objective of Intel's 300mm standards program was to intercept the supplier's Design Definition phase with concise standards in order to optimize the use of development resources. The goal was to reduce time to market and obtain the required product at the lowest possible cost. Failure to deliver standard in the Design Definition phase would have resulted in lost time and lost resources as suppliers expended additional resources to meet shifting requirments. By contrast, early engagement with suppliers in defining the vision and primary objectives helped the supplier understand the framework within which their equipment would fit. Involving suppliers during the negotiation stage creates an opportunity for disruption, but the insights provided to the suppliers is invaluable. It is of paramount importance that the suppliers be able to access the final specifications as soon as they are

passed so that maxiumum savings can be realized. The final critical link for standards is supplier education. It is important that suppliers obtain a clear understanding of the standard and its intended application so that misinterpretation does not occur.

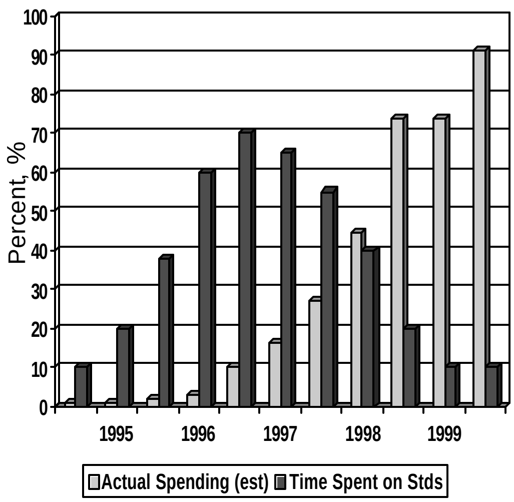

Figure 2: Estimated actual spending and time spent on standards activities by year.

Areas for Standards Improvements

It is clear that the critical link is matching the availability of standards with process equipment design cycles. Suppliers' access to the information contained within the standards is vitally important. A key opportunity to improve this process is reduction in the time between when a standard is passed and its publication. SEMI recognizes this problem and is currently working towards a 45 day commitment for 'superclean' standards and a 75 day commitment for all others. SEMI's performance has not met expectations. Intel and other IC makers are not satisfied with the progress towards this goal. SEMI needs to accelerate this program, as costs and leadtimes are directly affected with each delay in release.

A second area of opportunity is involvement of the equipment suppliers early in the standard creation process. The key is the suppliers' ability to access work in progress in order to accelerate their learning process. This can result in faster time to market and reduced development costs. It can be argued that this may increase the risk of suppliers' executing designs before the standards are finallized. However, it is to the suppliers advantage to be fully informed in order to correctly execute the standards with the minimal amount of delay and waste.

Intel Program Status

The semiconductor industry achieved consensus on 300mm as the next wafer size in 1994. By this time Intel had begun to actively pursue the development of a Factory Vision for 300mm manufacturing. This vision encompassed all aspects of IC manufacturing including detailed cost modelling, factory design, automation, equipment size and performance, environmental and safety issues. In 1995 Intel began discussing aspects of this vision with equipment suppliers and other IC makers through I300I. Intel also worked proactively through I300I with J300 to develop the Factory Guidelines which would define factory configurations and layouts. These shared visions solidified in 1996 and by 1997 equipment began to be tested against the expectations set forth. Testing and iteration of equipment proceeded through 1998 even as the health of industry severly declined. Many argue that the IC slump in 1998 delayed the 300mm conversion by a year of more. A potential benefit of this delay, however, was to allow suppliers additional time to understand and implement standards that were in development. By early 1999 it was apparent to Intel that the 300mm toolset was very close to meeting its program requirements. Intel announced the activation of its formal 300mm

conversion program in June 1999. This was founded on an assessment of the readiness of process equipment to meet technical and cost targets as well as compliance to standards which would enable an automated 300mm factory.

Intel's 300mm program is currently focused on selecting and delivering process equipment into the D1C development fab located in Hillsboro, Oregon. Installation of the Interbay AMHS is underway. Delivery of the process equipment set and Intrabay equipment is expected to start in January 2000. Characterization of this equipment and process development is expected to occur through 2001. Intel expects to ramp 300mm production in 2002 on a 0.13um process technology.

Intel Standards Assessment

Intel has learned some significant lessons concerning standards from its active program. These lessons were acquired through Intel's equipment selection process and from tools that have already been installed in Oregon.

The equipment selection process at Intel is a rigorous exercise in assessing capability and measuring compliance to requirement. Intel teams focusing on automation/process equipment related standards have been thoroughly testing process equipment for compliance. Test methods include both Intel specific tests and the I300I Factory Interface Maturity Assessment (FIMA) methodology. Overall assessment has revealed that compliance to the 300mm automation standards is quite good.

Two notable exceptions exist. Compliance to SEMI's E84 standard is very poor. E84 defines the handshake that must occur between the process equipment and the automated delivery vehicle. This standard is evolved from SEMI E23 which has existed for some time. However, E84 was not completed until very late in the 300mm tool development cycle. It is believed that this delay will have lasting impacts on the timeliness of implementation. Some suppliers waiting for the final version to be issued may face considerable investments in re-work time and resources. And compliance to E84 is vital to the proper functioning of an automated 300mm delivery system.

The second notable standards issue is the interoperability of FOUPs with E15.1 loadports. The original goal of the standards was to allow a FOUP from any manufacturer to be run on any E15.1 loadport. However, it became evident that a combination of non-compliance, ambiguous specifications and differing interpretations did not produce true interoperability. SELETE has produced a comprehensive study of the factors preventing true interoperability. It is believed that these issues can be resolved through the documentation of best practices and the use of calibration devices without major changes to the standards.

Conclusion

The early development of standards is a crucial element in intercepting process equipment development to reduce cost and time to market for wafer size transition. Important equipment design decisions are made early in the overall tool development cycle and accurate customer input at that time is key to optimizing cost and schedule. It is believed that the window of opportunity to affect cost or time savings for the 300mm conversion toolset has closed. Any changes in standards will induce additional cost in rework and must show compelling return on investment. Also, any changes made at this date

will not be implemented across the entire toolset for considerable time.

Containment of standards changes should be pursued in order to ensure realization of the cost savings and readiness for the transition. Only critical issues with the standards should be addressed. An initial assessment of 300mm equipment indicates good overall compliance with few exceptions. These exceptions are examples of recent standards that missed the window of opportunity or were open to interpretation Decreasing time to publication for new standards and earlier supplier access to standards in development were identified as areas for future improvement.

Acknowledgments
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